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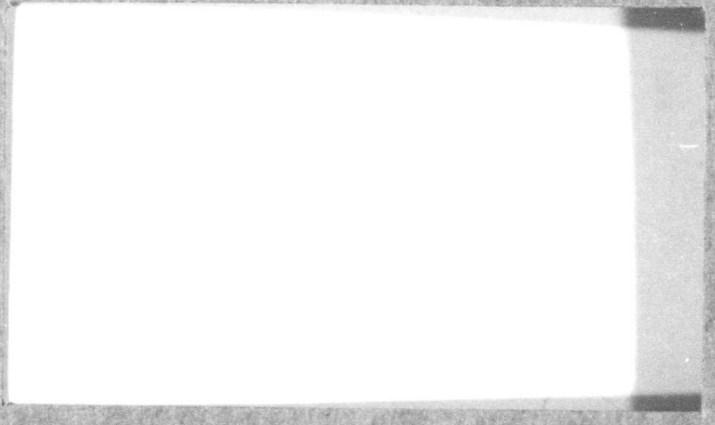

WOODS HOLE OCEANOGRAPHIC INSTITUTION

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6 SEA-SALT NUCLEI STUDIES.

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9 Summary Rept.,

By

10 A. H. Woodcock,
D. C. Blanchard
C. H. Keith

Summary Report
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INTRODUCTION

Methods used to sample atmospheric sea-salt particles, which were first developed under a former Office of Naval Research Contract N6onr-27702 (see Ref. 1), and subsequently under the subject Contract N6onr-27711 (NR-085-001) have been most useful in carrying out numerous studies of sea-salt aerosols. These methods made possible the sampling of salt particles having a weight range of about 1 to 50,000 $\mu\mu$ grams. At a relative humidity of 98% these particles have radii of from 2 to 50 μ. The principal studies which have evolved as a result of the above methods are listed and briefly discussed below.

IMPACT DEPOSITION OF ATMOSPHERIC SEA SALTS ON A TEST PLATE

This phase of the work is a by-product of the general study of atmospheric salt, and was intended to be of use to engineers studying the corrosion of structual steels exposed to the open air. Results are published in the Proceedings of the American Society of Testing Materials (2). These results clearly indicate the importance of winds in depositing significant amounts of corrosive salts on exposed steel surfaces. The work has stimulated additional studies of weather factors in corrosion under the leadership of Dr. F. A. LaQue of International Nickel Co., 67 Wall Street, New York City.

It is recommended that further study of the role of atmospheric salt in the corrosion of steels be left to corrosion engineers who are directly concerned with the problem.

GROWTH RATE STUDIES AND VAPOR PRESSURE MEASUREMENTS

During the period from July 1951 to March 31, 1952, studies were initiated in the laboratory on two phases of the over-all study of airborne sea-salt nuclei. These are:

1. The determination of the vapor pressure of concentrated sea water solutions.

2. The measurement of the growth rate of sea-salt nuclei under controlled humidity, temperature, and ventilation.

The vapor pressure work, which had the primary purpose of providing more reliable data for use in the isopiestic

method of determining nuclei weights, was initiated in the summer of 1951 by Mr. Kientzler. At that time he constructed an apparatus for measurement of the vapor pressure difference between concentrated sea water solutions and pure water. The pure water served as a reference of known vapor pressure. Considerable data were obtained during this period and presented by Mr. Kientzler as a thesis at Stevens Institute of Technology. Further measurements were performed in the summer of 1952 to expand and revise the initial data, and at the present date a technical report is being prepared which will present the method and final results in detail.

The measurement of growth rates was approached from both a theoretical and experimental viewpoint. Measurements were started during the fall and winter of 1951-52, and are continuing at the present time. Generally the indications obtained were that the time to grow to equilibrium radius increases most markedly with increasing humidity, and possibly decreasing ventilation, while increasing weight of salt seemingly increases the growth time to a lesser degree. The apparatus as constructed and as reported in Periodic Status Report No. 4 (4) has been modified as of the present date to permit more accurate control and measurement of ventilation. It is hoped that further measurements with this improvement will show a greater degree of correlation with the theoretical considerations outlined in Periodic Status Reports No. 3 (8) and No. 4 (4). It is hoped that these measurements can be completed shortly and presented as a technical report.

SEA-SALT PARTICLE DISTRIBUTION IN THE ATMOSPHERE

Three papers and a report have been distributed which give data on the sizes of salt particles in the atmosphere under various conditions.

In reference 1 it is shown that in stable air the salt tends to remain near the sea surface, and that in unstable air it is almost uniformly distributed from the surface up to cloud base (see pp. 185 and 193 of ref. 1).

In trade-wind areas, the relatively clear air among convective clouds contains less salt than is present in the sub-cloud region, and above the clouds the amount is one or two orders of magnitude less than that in the sub-cloud air (see refs. 3 and 4).

The salt in marine winds is observed to be carried inland 100 km. without noticeable reduction in amount (ref. 3, fig. 4).

The amount of salt at cloud levels increases greatly as the wind force over the sea becomes greater (see ref. 4, fig. 1).

It is recommended that measurements be made of salt particles in marine winds at greater distances inland, since there is evidence that these particles act as nuclei for the formation of raindrops (see ref. 3).*

ATMOSPHERIC SALT PARTICLES AND RAINDROPS

The initial phases of this study are complete and the results are published (see ref. 3). These results suggest that the large salt particles become raindrops within clouds, probably by condensation and accretion processes. ** Recent rain-sampling experiments on Hawaii, T. H., which were designed to test the salt-particle raindrop hypothesis, are now being studied and they seem, in general, to support the hypothesis.

The testing of the salt-particle raindrop hypothesis has led to some interesting precipitation studies. These were initiated and carried out in order to obtain the variations in raindrop size distributions from one cloud system to the next. Concurrent with these measurements a study was made of the variation of rain water chloride content with intensity. Both programs involved the development of simple instrumental techniques (see Periodic Status Reports No. 2 and 3).

A theoretical study indicated that both drop size measurements and bulk water samples should be obtained at cloud base or within the cloud system itself. It was shown in Periodic Status Report 3 (see ref. 8) that, under normal conditions, a considerable amount of evaporation occurs as rain falls from cloud to ground. It is quite possible that all drops < 0.5 mm. diameter are completely evaporated. In the same report it

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* At the suggestion of one of the project members, similar measurements are being initiated over continental Australia by the cloud physics group headed by Dr. E. G. Bowen, Division of Radiophysics, C.S.I.R.O., University Grounds, Sydney. At the request of the Australian government, a member of the project recently visited Dr. Bowen's group for the specific purpose of teaching them the techniques used here to sample sea-salt aerosols.

** This phase of the sea-salt nuclei study has led directly to the formation of a new cloud physics research team in Honolulu, T. H. This new project is under the leadership of W. A. Mordy of the Pineapple Research Institute, Box 3166, Honolulu, T.H.

was pointed out that rain, falling in the sub-cloud layer, collides with the airborne salt particles. Reasonable assumptions as to size distribution of the salt particles, fall distance of the raindrops, relative humidities, etc., lead to the result that the salt added by accretion is nearly of the same order of magnitude as that normally found in rain. In view of these results all sampling of rain was carried out well within the boundaries of the cloud system.

The raindrop size distributions and chlorinities all showed striking variations, for the same intensities of rainfall, from one cloud system to another. Indeed, including the maximum and minimum of the drop distribution samples, they still are considerably different than distributions obtained elsewhere. * It is the immediate aim of the project to examine the drop size distributions, chlorinities, and salt particle measurements in detail, in an effort to correlate the entire data from Hawaii into a reasonable explanation of the production of rain from non-freezing clouds.

Recommendations concerning this work should await the final results of the analysis of the Hawaii precipitation data.

ORIGIN OF ATMOSPHERIC SALT PARTICLES

Laboratory experiments have shown that the bursting of small air bubbles at the surface of sea water produces salt particles of the same size range as those found at cloud levels. Bubbles smaller than one mm in diameter seem to be the most effective producers of small droplets. On the sea the foam patches resulting from breaking waves are observed to be source regions for many salt particles having a size comparable to that of the particles found at cloud levels. The great increase in the number of airborne particles with greater wind force (see ref. 4, fig. 1), is attributed to the production of more bubbles by the increased number and size of the "white caps".

In Periodic Status Report No. 3 (8), a start was made on the development of a theoretical basis for the bursting bubble; however, the complexity of the bursting process precludes further analysis until experimental data are obtained on the size and height of projection of droplets as a function

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* The manner in which this effects the radar reflectivity, Z, a function of the rain echo as received by a radar, has been discussed in a paper presented by D. C. Blanchard at the 3rd Radar-Weather conference at McGill University, Montreal, Canada, September 15-17, 1952.

of bubble size and surface conditions. Obtaining this data is planned as the primary objective of laboratory studies of this phenomenon.

The calculations performed last fall indicate that reduction of the surface tension of a water surface permits a given bubble to ride higher on the surface, which should lead to a shorter time between coming to rest at the surface and bursting, which agrees with the observed phenomenon of a smaller foam patch on coated surfaces. Also this shorter resting time should lessen the rapid coalescence of small bubbles at the surface, thus presumably increasing the number of airborne particles produced from these small bubbles.

From these preliminary observations and calculations it is concluded that bubbles are probably a major source of salt particles in the air. Further laboratory and field studies of this source of droplets are planned in the near future.

SALT PARTICLES IN THE NE TRADES AND RAINFALL ON OAHU, T. H.

Measurements of salt particles and of rain made in Hawaii during ten days in June 1951 suggested that increased rainfall was associated with increased numbers of larger salt particles in the trade winds (see ref. 4, figs. 2, 3, and 4). During the winter and spring of 1952, many more similar measurements were made during a total of thirty days. These data are not yet analyzed, and it is not possible as yet to draw conclusions from them. It is expected that work with these data will be completed during the fall of 1952.

THE RELATIONSHIP BETWEEN CLOUD DROPLET DISTRIBUTION AND SALT PARTICLE DISTRIBUTION BENEATH THE CLOUDS

In collaboration with Mr. P. Squires of C.S.I.R.O., Div. of Radiophysics, University Grounds, Sydney, Australia, samples of salt particles were recently taken in oceanic air (from the South Indian Ocean) a short distance beneath cumulus clouds in which another aircraft was sampling cloud droplets. Through a comparison of the distribution of cloud droplet mass and salt particle mass, we expect to be able to extend the cloud droplet distribution spectrum in the direction of larger and more sparsely distributed drops. These samples are now being studied, and it is expected that a joint paper will result from the work.

SALT PARTICLES AND SEA FOG DROPLETS

Early work with airborne salt particles and sea fog droplets in the Woods Hole area indicated that each fog drop contained a salt nucleus and that the number of fog drops corresponded to the number of the larger salt particles. However, recent work in Japan by Daisuke Kuroiwa (ref. 6), showed that only 11 in 32 sea fog droplets, which were examined with an electron microscope, contained hygroscopic nuclei.

An investigation of the role of sea-salt particles in the formation of marine fogs should contribute to the understanding of these fogs, which have been controversially discussed in recent meteorological literature (7). We hope to start a study of salt nuclei and fog during the spring of 1953.

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